

THE APOCALYPSE EQUATION

$$AP = 1 - [1 - p]^{n(U+S)}$$

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The Apocalypse Equation

In his essay in the September-October issue ("Too many nuclear weapons," page 17), Joel E. Cohen has rightly pointed out that the possibility of the accidental explosion of a nuclear weapon may pose a substantial danger to humanity. While his statistical analysis is a valuable contribution to the subject of nuclear-weapons accidents, further insights into the seriousness of the problem can be gained from mathematical equations that accurately give the probability of an accident over a period of time. Generically, these equations may be called Apocalypse Equations (AE).

To explain them, we might consider the chance of the accidental launch of a strategic missile. A form of the AE that lends itself to simple algebra is:

$$AP = 1 - [1 - p (U + S)]^n$$

where AP = the probability of an accidental launch of a nuclear missile over a period of time; p = the chance of the accidental launch of any given missile over any 24-hour period; U = the number of United States missiles; S = the number of Soviet missiles, and n = the number of days. To show how the equation works, let's say that we want to know the chance of an accident over a one-year period. Then $n = 365$ (days); $U = 2,000$ (approximately); $S = 2,000$ (approximately); and we don't know the exact value of p , but let's assume it's very, very small, like 10^{-8} , or one chance in one hundred million.

Inserting these values into the AE we find that the likelihood of an accidental launch in one year is 1.4 percent. In forty years, the likelihood is more than fifty percent.

Since there have been thousands of missiles in place for more than a decade, the equation already has been "working" for some time.

The value of p is the only factor we don't have the data to approximate. It may be argued that p is much smaller than 10^{-8} . On the other hand, it may be larger. Probably p could be calculated for missiles in much the same way as a team of M.I.T. scientists, under the leadership of Norman Rasmussen, has calculated the probability of a nuclear-reactor accident. The data about missile design and control that would make possible a calculation of p probably exists in military files.

It's obvious that the value of p is of vital importance to the human species, for it enables us to calculate how much time we likely have to stop the arms race and abolish nuclear weapons. People concerned about this matter, therefore, should demand that the governments of the United States and the Soviet Union, and other countries that have nuclear missiles, make public the data for calculating p .

The form of the AE given produces a close approximation. A closer approximation can be reached by the equation $AP = 1 - e^{-np(U+S)}$, where $e = 2.71828$. An equation that produces an exact result is $AP = 1 - (1 - p)^{n(U+S)}$.

The concept of p can be varied to mean the possibility of an accidental nuclear-warhead explosion. In this case, $U + S = 50,000$.

All these equations produce logarithmic curves that approach certainty, and have a number of political implications. They show why increasing the number of missiles increases the likelihood of an accidental missile launch, and at least in that respect is not in the interest of the country. They also show why there is more to the problem of preventing nuclear war than just keeping irresponsible fingers off the "nuclear trigger." That's important, but as long as the missile systems exist, the chance of a catastrophic accident approaches certainty, no matter whose finger is on

the trigger. For these reasons, nuclear "containment" is a policy that may work in the short run, but in a few decades is likely to produce catastrophic accidents that could result in nuclear war.

The equations can be given a religious interpretation. Nuclear-missile systems have made it possible to statistically predict an apocalyptic event. An insight into the potential magnitude of the event can be gained by considering the destructive power of a Trident submarine, which within twenty minutes can launch 406 nuclear bombs, each of which has an explosive power ten times that of the bomb that destroyed Hiroshima. The U.S. plans to have thirteen of these submarines on station soon. Presumably the Soviet Union will have its own fleet of equally destructive submarines.

When he was in the United States recently to receive the 1981 Franklin Medal, Stephen Hawking, the noted British astrophysicist, had this to say about accidental war:

Even if the probability of war occurring by mistake or miscalculation is low in any one year, the cumulative probability over the next hundred years is frighteningly high.

This is by far the most fundamental problem facing our civilization, and it is of much more importance than any political issues that divide us. We should press for immediate disarmament, unilaterally if necessary. We do not want a future archaeologist from another star to record that the human race destroyed itself over an argument about the economic organization of production or over a few square miles of territory.

BRADFORD LYTTLE

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From the Letters section

Nuclear-arms paranoia

My heartfelt thanks to Dr. John E. Mack for his perceptive article, "But what about the Russians?" (March-April, page 21). Many of us are concerned about "nuclear-arms paranoia" and are trying to persuade our leaders to do something about it. We have been stuffed with facts about the dangers of nuclear warfare, but an understanding of the unconscious motives of those who are possessed by this paranoia, along with a gut realization of what such warfare would do to millions of people, can do even more to get us involved. Especially moving were Mack's quotes from concerned teenagers.

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When Mack finally gets around to the question, "... What about the Russians?" he gives non-answers.

He writes: "We are utterly ignorant of each other, of our cultures, histories, and intentions." Is he serious? I am old enough to recall similar nonsense about Hitler's Germany. Wiser heads who suggested reading *Mein Kampf* as an earnest of Nazi intentions were pooh-poohed. Those who urged a hard line against Hitler were called hysterical. Those who saw evil in Fascism and Nazism were said to be believers in a devil theory. Germany, we were told, sees itself ringed by hostile powers. "Once Hitler incorporates the Saar, absorbs the Rhineland, Austria, the Sudeten-Germans . . . Germany will be content."

George Kennan, approvingly quoted by Mack, writes of "the commonality of many of their problems and ours as we both move inexorably into the modern technological age." What common-

ality? Improved gulags? Are we to take Kennan's wishful thinking as a surety of Soviet intentions?

Since the Bolsheviks seized power in 1917, the rulers of the Soviet Union have murdered, conservatively estimated, some sixty million of their own people. How many imprisoned? Six million political prisoners at any one time, Solzhenitsyn estimates. This does not count the dead or imprisoned in the Soviet satellites, in Communist China, Cuba, North Korea, Vietnam, Cambodia, Afghanistan—wherever Communism has ruled. How many witnesses, Dr. Mack, do we need to attest to the character of Soviet culture, history, or intentions?

To fear such a system appears to me profoundly rational. To consider it evil is commonsense. To trust it, foolhardy. To oppose it, morally imperative. It does not help the cause of freedom and peace to paper over Soviet realities. Or to bury our heads in the sand like the ostrich and ignore Soviet intentions.

Ours is a difficult task, and the first priority is to defend the West and its freedoms. Throughout the postwar era, the American deterrent has kept the nuclear peace. Renouncing it now would bring on war. It is the unprecedented Soviet build-up of nuclear and conventional arms that has created the present atmosphere of peril.

It is not "better to be dead than red," it is better to be neither. Sixty million souls surely attest to that. Deterrence is not as pleasant as Mack's illusions, but it will keep us—and Mack—alive and not red.

Pace, Dr. Mack. It is not the "hostility and fear dominating U.S.-Soviet relations and the nuclear proliferation growing out of this fear that most acutely threaten our survival," it is the totalitarian night.

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Many thanks to Mack. I had begun to fear that the subjugation of Eastern Europe and the invasion of Afghanistan were signs that the Soviet Union might really be aggressive after all.

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In his article, Harvard psychiatry professor John E. Mack joins Berkeley professor Michael Nagler in calling for a "paradigm shift" away from aggressiveness and belligerence and toward peace. Students of the social sciences will recall that the idea of a paradigm shift was developed by Thomas S. Kuhn in his 1962 book *The Structure of Scientific Revolutions*. Kuhn's theory is complex, but in essence it is that the scientific understanding of the world progresses by means of sudden shifts

in perspective in which one model or "paradigm" replaces another. An example of this idea offered by the physical sciences is the shift from Newtonian to Einsteinian physics. In the social sciences Marxists have argued that Marxism is a paradigm shift beyond classical economic theory. Under any circumstances, paradigm shifts become possible when scientific research has accumulated enough new information to make possible a theoretical synthesis that is more inclusive than preceding theories, and differs from them in important ways. The appalling dangers to the entire human species inherent in nuclear arsenals and the arms race certainly suggest that a fresh perspective is needed in international relations—one that can avert nuclear war and open up the possibility of unlimited human development. Fortunately, while science has made possible nuclear weapons, it also can suggest the best ways to abolish the weapons and avoid nuclear war.

A key insight is that it's now possible to develop a statistical analysis of strategies for ending the arms race and averting nuclear war. This makes it possible to at least partly remove the evaluation of strategies from the realm of opinion and conjecture, and place it on an objective, scientific footing. For everyone who understands and respects the scientific method, the value in being able to do this is obviously considerable.

To facilitate analysis, we can divide strategies for ending the arms race and avoiding nuclear war into four kinds. The "Establishment" strategy, which has United States and Soviet versions, is to strive for either arms superiority or arms parity, that is, to continue the arms race indefinitely on the assumption that the other side won't be able to keep up. The U.S. version rests on the conjecture that because the Soviet Union has only half the industrial base of the United States, and an inflexible, totalitarian political system, the Soviet Union's economy will be exhausted by the military expenditures exacted by arms competition, and that this will lead to crippling ethnic and nationality conflicts, and perhaps revolution. The Soviet version stems from the theoretical Marxist promise that because of its capitalist character, U.S. society must undergo a socialist revolution generated by class conflict. The parallel between the U.S. and Soviet theories is striking.

Arms control, a second strategy, preserves the principle of "deterrence," but seeks to control the arms race through bilateral agreements verified by inspection. Arms control of the type expressed by the SALT I and SALT II agreements seeks to slow the arms race. "Freeze" arms control seeks to halt the nuclear-arms race at its present arsenal

levels. George F. Kennan has proposed halving nuclear arsenals. Key to all arms-control agreements is the inspection, which is designed to eliminate the need for mutual trust.

Unilateral disarmament is a fourth strategy. It can embrace unilateral conventional as well as nuclear disarmament, and also the concept of bilateral disarmament not contingent upon agreements and inspection processes. The strategy of unilateral initiatives has the purpose of generating trust and encouraging an atmosphere of détente through unilateral, reversible disarmament initiatives that don't fundamentally jeopardize the military strength of the nation that undertakes them.

Since the Establishment strategy is dominant, let's examine it first. To prove it unscientific, we must show statistically that the arms race will result in nuclear war.

Under present circumstances, a catastrophic event involving a nuclear weapon could trigger a nuclear war. Such an event might be the launching of a missile. Although one hopes that the leaders of a nation struck by a missile would remain completely rational and cool, it's certainly possible that the sight of one or more of their country's cities or military bases in ruins, and the dead and mutilated bodies of thousands of their countrymen and -women, would stimulate them to make a retaliatory gesture. Such a gesture could easily escalate into all-out war. Let the letter p stand for the chance that any given missile will be launched during a 24-hour period.

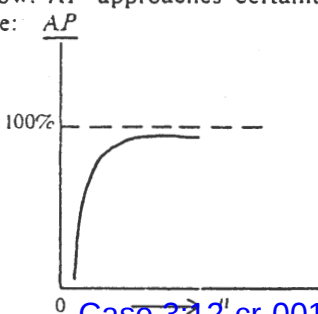
We are most interested in the chance of a missile launch over an extended time. An equation that will give this probability to a high degree of accuracy for the values that most interest us and can be understood by anyone with a background in high-school algebra is:

$$AP = 1 - (1 - p)^{n(U+S)}$$

where: AP = The chance of a missile launch over an extended period;

n = The number of days in the period;
 U = The number of U.S. missiles; and
 S = The number of Soviet missiles.

This equation has two particularly important characteristics. One is that it's an exponential equation that produces a logarithmic curve such as that below. AP approaches certainty over time:



The other is that we immediately have values for all of the variables in the equation except p . We know that $U = 2,000$ (approximately), and $S = 2,000$ (approximately), and that the value of n is a matter of our choice. We can gain some insights into p 's value by the exercise of a little imagination and some mathematical experiments.

The value of p must be very small. If it weren't, a missile would have been launched by now, and we'd probably be dead. If we let

$$p = 10^{-7} = \frac{1}{10,000,000}$$

decide that we want to know what AP will be in ten years ($n = 3,650$), and put all of our values into the equation, we find that AP is equal to about 77%. That value is probably too large. Thousands of missiles have been around for more than ten years, and one hasn't been launched. Therefore, let's try a smaller value for p , say,

$$p = 10^{-8} = \frac{1}{100,000,000}$$

At $p = 10^{-8}$, in ten years, AP equals about 14%. That value is consistent with our being alive. It's therefore reasonable to believe that p 's actual value is 10^{-8} or less.

It's possible to learn still more about p 's value. For example, a missile might be launched by the failure of some mechanical or electrical component in its launch mechanism. The chance of such a failure could be calculated in much the same way that a team of Massachusetts Institute of Technology scientists under Dr. Norman Rasmussen's direction calculated the chance of a power-reactor accident. Some research along these lines already has been done (see "Too many nuclear weapons," September-October, page 17).

Also, a missile might be launched because of the psychological breakdown of its launching crew. Here, too, relevant research already has been done into the psychological stability of the personnel who control nuclear weapons. Calculation of these probabilities could provide a minimum, or base value, for p . The chance of other possible causes of a missile launch, such as a decision by a strategic-weapons command center, a national leader, or a terrorist group, would be more difficult to quantify and calculate, but could be added to the base value. The value of p would become greater in times of international crisis.

Still other insights provided by the equation are that the more missiles there are, the higher is the likelihood of war, and that although p may be astronomically small, over a period of only a few years, the chance of war can become alarmingly high. It's obvious that p 's value is of great importance to

the human species. Governments should be required to make public all information that could bear upon the calculation of p .

Once we realize that we actually can calculate the probability of a missile launch—the outbreak of nuclear war—the Establishment strategy, be it the U.S. or Soviet version, is no longer rational. It represents the assumption that speculations have a higher degree of probability than the logarithmic curve of the equation. There's no way to quantify the conjectures of U.S. or Soviet strategists concerning the probability of a collapse of each other's cultures for economic or political reasons. On the other hand, it is possible to calculate the probability of the outbreak of nuclear war. To base policy on conjecture rather than on statistical projection is unscientific.

In addition, the probability equation shows that the leaders of the U.S. and Soviet Union are playing a lethal global game with the human species similar to Russian roulette. In Russian roulette, the players put one bullet into the chamber of a revolver, then in turn take up the weapon, spin the chamber, place the muzzle to their heads, and pull the trigger. In U.S. - Soviet roulette, H-bombs are the bullet, missiles the revolver, the players point the weapon at each other, and everyone can be killed when the gun finally goes off. Also, the players keep putting more bullets into the chamber, which increases the chance of the gun firing.

The equation provides still another insight about the Establishment strategy: A national leader who claims that he or she can at once maintain a strong nuclear deterrent and preserve peace is either unaware of the character of modern strategic weapons systems, or is deceiving us.

Of the remaining three strategies, unilateral initiatives are probably unable to stop the arms race. Any reversible disarmament step will appear to be a deception, a ruse, and won't generate trust. No genuine disarmament step is likely to result from this strategy.

Of the two remaining strategies, SALT-type arms control can slow but not stop the arms race. Arms control will increase the period within which nuclear war will become probable. Freeze arms control will lock nations into the present values of the equation. That will further increase the period within which nuclear war will become probable but won't prevent nuclear war. Both SALT-type and freeze arms control continue the game of roulette, but at somewhat less risky levels than the Establishment strategy.

As arms control proceeds and reduces nuclear-weapons levels, it can steadily increase the odds of the roulette

game. Arms control's main difficulty lies with inspection. The SALT treaties have shown how difficult and time consuming it is to establish satisfactory verification of agreements. Freeze advocates claim that inspection of freeze agreements would work because large missile and bomber bases, and missile and bomber production and assembly facilities, can be monitored by satellites, and that there are so many nuclear weapons that minor treaty violations won't matter. This suggests that arms control will work only at levels of nuclear arms about equal to present ones, and that's inadequate for preventing nuclear war. The difficulty of developing satisfactory inspection procedures for lower levels of nuclear weapons can be understood by recalling that nuclear weapons can now be made so compact that hundreds will fit into a small room, only a few weapons are needed to give military superiority over conventional arsenals, the U.S. and the Soviet Union have tens of thousands of weapons, and bombs can be delivered by many means other than large missiles, such as cruise missiles, submarines, disguised boats, disguised airplanes, and even trucks, automobiles, and large suitcases. The temptation for a nation engaged in arms control to hide a cache of weapons would be enormous, and no way of preventing this from happening seems available.

Despite arms control's difficulties, freeze agreements followed by attempts to reduce arms levels are plainly more rational and scientific than the Establishment's strategy.

Unilateral disarmament would immediately reduce many of the values in the probability equation by about half and therefore make war less likely. It's unlikely that a nation engaging in unilateral nuclear disarmament would suffer a nuclear attack. First-strike attacks are made probable by the increasing armaments of an "enemy," not by decreasing armaments. The present fears about a "window of vulnerability," and

the Japanese attack on Pearl Harbor, which was designed to halt the growing power of the U.S. Pacific Fleet and Air Force, are examples of this principle. A nation with nuclear arms would have strong reasons *not* to attack a nation that was disarming. An attack would poison the ecosphere shared by everyone, risk a retaliatory attack, destroy valuable human and other resources, and wreak great damage to the attacking nation's global political image. Since nuclear weapons are inherently dangerous and costly, the rational response to unilateral disarmament would be to quickly reduce one's own arsenals of nuclear weapons.

Thus, unilateral nuclear disarmament probably would greatly decrease the likelihood of nuclear war.

A nation engaging in unilateral nuclear disarmament would have good reasons to reduce its conventional arms as well. Conventional arms are no match for nuclear arms, and their use against an enemy armed with nuclear weapons would invite a nuclear attack, as the bombings of Hiroshima and Nagasaki show. Furthermore, conventional weapons are expensive and contribute to inflation.

The principles that make unilateral disarmament an effective way to end the arms race between the U.S. and the Soviet Union, and to prevent nuclear war, would apply to arms races between other nations—for example, to the arms race between the Soviet Union and China.

Any nation that practiced unilateral disarmament would be wise to pursue nonmilitary alternatives for defending its values and institutions. Massive economic-aid programs to combat poverty and other causes of cynicism, desperation, and aggression; the development of global institutions that would promote political freedom and economic justice; and preparation for non-violent resistance to cope with the possibility of invasion and occupation are examples of alternatives.

International relations conducted in such a manner might or might not be expressions of a new paradigm. Certainly, they would be more rational and scientific than the strategies based on conjectures now being followed by the superpowers, which can be shown by statistical analysis to be propelling the world toward nuclear war.

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Nuclear War Is Inevitable—Unless...

In terms of mathematic probability, a nuclear war is inevitable and humanity's chances of survival are pitifully small. So contends Prof. Martin Hellman of Stanford University, a brilliant 40-year-old mathematician who is internationally recognized for his expertise in statistics, probability and cryptography.

Hellman's conclusion that nuclear war is inevitable is based on his analysis of facts through a mathematical process called the "two-step Markov principle." Since this reporter readily admitted that Markov's principle was too complicated for him, the good professor explained it in terms of Russian roulette.

"In Russian roulette," he began, "you take a revolver with six chambers and load only one. You spin the cylinder, place the barrel against your brain and pull the trigger. There is one chance in six of getting killed. But that's if you play the game only one time. If you play twice, the two chances of being shot reinforce each other, and the odds are almost one in three of killing yourself. After 10 trials, the odds are 84% that you're dead; after 20 trials, 97%. And if you continue to play, the odds become 100% that you will shoot yourself. It's inevitable. In mathematics, we say it happens 'with probability one.' It's certain.

"It doesn't matter if your gun has six chambers or 60 or 600. The smaller probability of killing yourself at each trial prolongs the game, but it does not change the ultimate outcome. You still get shot with probability one."

The professor was then asked to explain simply the analogy of Russian roulette to the inevitability of a nuclear war.

"No one in his right mind," he pointed out, "would play Russian roulette even once. Yet we are continually playing nuclear roulette in which the entire world is at stake. I concede that four decades have elapsed since Hiroshima and Nagasaki without another world war, making people believe nuclear arms are useful in maintaining the peace—that deterrence works. But the real question is not whether nuclear weapons have postponed World War III; the real question is whether they have eliminated its possibility



Prof. Martin Hellman of Stanford

forever. It can only happen once.

"Yet we keep playing nuclear roulette, pulling the trigger more often than most people realize. Every small war is pulling the trigger. Every threat to use violence is pulling the trigger. Every day that goes by in which a missile or a computer can fail is pulling the trigger. Each action in our old-fashioned way of thinking generates another chance of triggering the final global holocaust."

Would a nuclear freeze followed by the gradual destruction of all nuclear weapons prevent the inevitable death of this planet?

"A nuclear freeze," Hellman maintained, "followed by even total disarmament, is not the answer. Our knowledge of how to build nuclear weapons makes disarmament relatively useless. Suppose we outlaw nuclear weapons but don't change our mode of thinking about war in general; my belief is that we may then be more likely to get into a conventional war with the Soviets. Just think that through for a minute. Suppose we engage in a conventional war against the Soviets. The side that is losing will surely be tempted to quickly rebuild nuclear weapons in an effort to save itself.

"I'm convinced the only way to survive nuclear roulette is to stop playing the game, to put down the gun globally, to move beyond war. If we want to avoid the world's imminent suicide, we must shift totally the way we think about war. We no longer can accept it as a means of settling disputes, as an extension of politics or as an innate ingredient in the nature of man."

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